Limb Correction of RGB Composite Imagery for Improved Interpretation

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1. Red-Green-Blue (RGB) Composites

- **Combine information from several channels** into one composite image to address a specific forecast problem
- Aids in **quick, real-time analysis** of atmospheric processes
- Products from Aqua and Terra MODIS and VIIRS on Suomi NPP are **proxies for future GOES-R RGB products**

RGB Product	Application	General Wavelengths	MODIS Channels	VIIRS Channels
Air Mass	Jet Streaks, PV Analysis	6.7 - 7.3 (WV) 9.6 - 10.8 (O3 - lw win) 6.7 (WV, inverted)	27 - 28 30 - 31 27	Cx - Cy Cz - M15 Cx
Dust	Differentiate Dust from Cloud	12.0 - 10.8 (split win) 10.8 - 8.7 (l/w win) 10.8 (lw win)	32 - 31 31 -29 31	M16 - M15 M15 - M14 M15
Night Microphysics	Fog/Low Stratus, Thin Cirrus	12.0 - 10.8 (split win) 10.8 - 3.7 (lw - sw win) 10.8 (lw win)	32 - 31 31 - 20 31	M16 - M15 M15 - I4 M15
24 Hour Microphysics	Fog/Low Stratus, Thin Cirrus	12.0 - 10.8 (split win) 10.8 - 8.7 (l/w win) 10.8 (lw win)	32 - 31 31 - 29 31	M16 - M15 M15 - M14 M15

Fig. 1. RGB composite recipes for MODIS and VIIRS. Channel differences are indicated by a minus sign. Cx, Cy, and Cz are water vapor and ozone channels from CrIS for wavelengths 6.7, 7.3, and 9.6 micrometers, respectively.

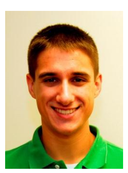
2. Challenges with RGB Composites Derived from Polar Orbiters

A) Limb Effect (Limb Cooling)

- **Interferes with qualitative interpretation of RGB composites at large scan angles**
- Occurs as satellite scans from nadir to limb, increasing the optical path length of the absorbing atmosphere
- **Causes anomalous cooling** of 5-10 K on the limb in water vapor and ozone channels
- Uncorrected RGB composites from polar orbiting instruments, such as MODIS and VIIRS, can only be reliably interpreted close to nadir

B) Calibration Differences (Sensor Bias)

- RGB products from multiple satellite sensors are often used jointly to provide a more temporally continuous product and better track atmospheric features over time
- MODIS and VIIRS do not have the exact same channels as SEVIRI or GOES-R ABI, and there are additional sensor differences between Terra and Aqua MODIS
- **Calibration differences** between sensors:
  - **Limit the use of proxy products**
  - **Make comparison of similar products from multiple sensors difficult**



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Air Mass

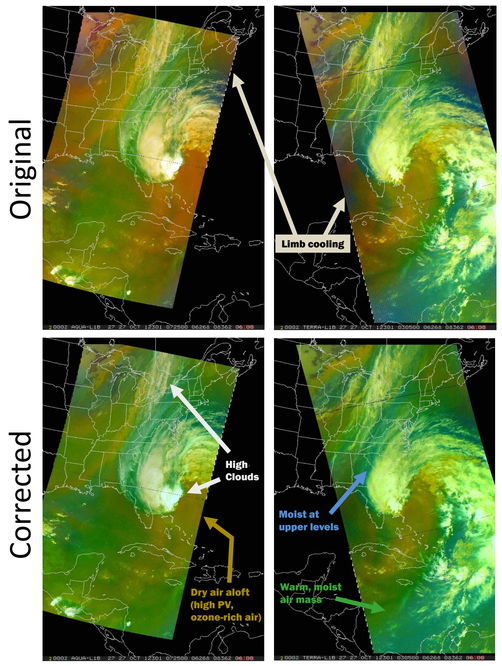

Fig. 2. 2012 October 27 Aqua (0725 UTC) and Terra (0305 UTC) MODIS Air Mass RGB composites (original and corrected) showing a developing Hurricane Sandy with a dry air intrusion.

Dust

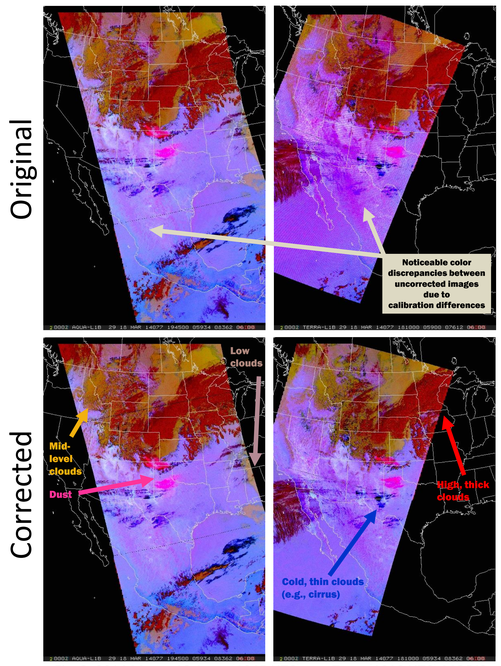

Fig. 3. 2014 March 18 Aqua (1945 UTC) and Terra (1810 UTC) MODIS Dust RGB composites (original and corrected) indicating airborne dust over the Texas panhandle.

Night Microphysics

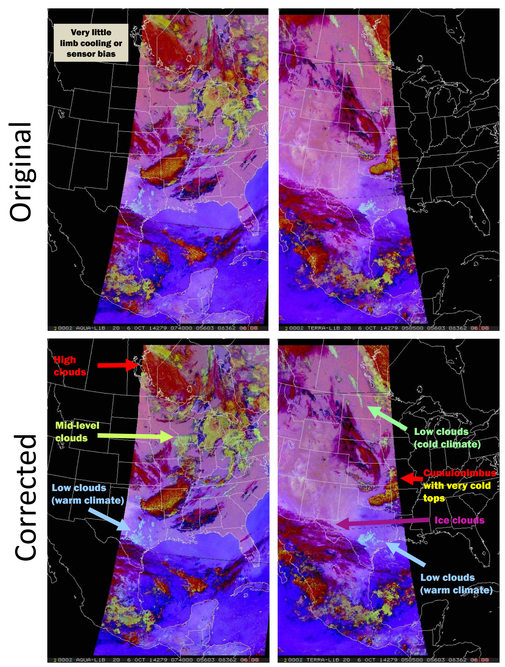

Fig. 4. 2014 October 06 Aqua (0740 UTC) and Terra (0505 UTC) MODIS Night Microphysics RGB composites (original and corrected) indicating the presence of fog and low clouds over Texas (light blue) and central North Dakota (light green). Limited to night use only.

24 Hour Microphysics

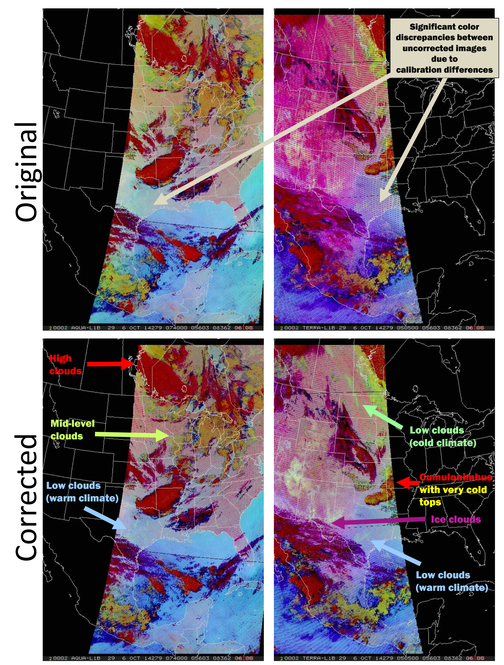

Fig. 5. 2014 October 06 Aqua (0740 UTC) and Terra (0505 UTC) MODIS 24 Hour Microphysics RGB composites (original and corrected) indicating the presence of fog and low clouds over Texas (light blue) and central North Dakota (light green).

3. Limb Correction

- Using a globally distributed subset of ECMWF model profiles, brightness temperatures were simulated for varying scan angles (0°-60°) for each profile.
- The best fit slope between the change in brightness temperature from nadir to the limb and the natural log of the cosine of the satellite scan angle (θ) is defined as the limb correction coefficient (C).
- A quadratic fit was applied to the distribution of C versus latitude to obtain a representative correction coefficient for each latitude, C_R.
- C_R was applied to calculate the limb-corrected brightness temperature (T_{corr}) from the uncorrected brightness temperature (T_{raw}) given the scan angle:

$$T_{corr} = T_{raw} - C_R ln(\cos\theta)$$

4. Bias Correction

- **Nadir brightness temperatures for MODIS were adjusted to match the nadir brightness temperatures of SEVIRI**
- Limb effect is not a factor at nadir, so any differences in measured brightness temperature between the sensors can be attributed to sensor bias

5. Results

- **Removal of anomalous cooling** near swath edges (Air Mass)
- **Very similar appearance of MODIS RGB products** between Terra and Aqua after bias correction (Dust, 24 Hour Micro.)
- Corrections had very little impact on Night Microphysics RGB

6. Advantages of Limb/Bias Corrected RGBs

- **More accurate representation** of atmosphere and surface
- **Ability to utilize the full satellite image**, rather than just part of the image close to nadir
- Seamless transition between adjacent or overlaid RGB composite images
- **Availability of high quality proxy products** to prepare for GOES-R era
- **Increased confidence in interpretation of RGB features**
- **Improved forecaster situational awareness**
- No longer limited to using just two overpasses per day from a single instrument, but have ability to jointly use the same RGB product from several sensors

7. Future Work

- Extend the limb and bias correction methodology to MODIS and VIIRS infrared channels for additional RGBs
- Investigate limb effect for geostationary satellite channels, such as Meteosat-10 SEVIRI, GOES-R ABI, and Himawari AHI.

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